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Manual and Transducer Groundwater Levels from Test Wells at Los Alamos National Laboratory, 1992–2003

Los Alamos
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Glossary of Terms

amsl	above mean sea level
DT	Deep Test (Well)
Depth to Water (DTW) Measurement	The measured depth to water from the Measuring Point expressed in feet. The DTW measurement is usually obtained with a weighted sounder attached to a graduated non-stretch tape.
Gage Pressure	Pressure measured relative to (that is, above) atmospheric pressure.
Ground Elevation	The elevation of the ground surface of the well expressed in feet above mean sea level. If the well has a concrete surface pad, usually the elevation of the top of the concrete pad. If a brass cap is present to identify a well, usually the elevation of the brass cap in the concrete pad.
Measuring Point (MP)	The documented point from which depth to water is measured.
Measuring Point Elevation	The elevation of the MP, calculated by adding the MP height above ground elevation to the ground elevation.
Measuring Point Height	The MP height in feet above the Ground Elevation
Pressure Head	The height in feet of a column of water that can be supported by the gage pressure measured at a point in a well.
Pressure Transducer (Transducer)	A device that measures pressure. There are two types of pressure transducers, those that measure absolute pressure, and those that measure gage pressure. The transducers used in test wells have a vent line that extends to the surface that is exposed to one side of the pressure-measuring device so that pressures are measured relative to atmospheric pressure.
psia	Unit of pressure measurement in pounds per square inch absolute.
psi	Unit of pressure measurement in pounds per square inch.
Reference Level (RL) or Reference Datum	The elevation of the surface of the water in a well at the time of installation of the transducer
Surface Elevation	Same as Ground Elevation
TOC	Top of Casing, usually the measuring point for a DTW measurement.
TW	Test Well
Water Elevation	The elevation of the surface of the water in a well, expressed in feet above mean sea level
Water Level	1) The DTW in a well below ground surface expressed in feet, or 2) The Water Elevation expressed in feet above mean sea level.

Manual and Transducer Groundwater Levels from Test Wells at Los Alamos National Laboratory, 1992–2003

by

Richard J. Koch, David B. Rogers, Neal J. Tapia, and Stephen G. McLin

Abstract

Pressure transducers have been used to measure water levels in the regional aquifer monitoring wells (test wells or TWs) at Los Alamos National Laboratory (LANL) since 1992. The transducer water level data provide relatively continuous measurement of groundwater level, and manual measurements provide a reference datum for the transducer data. The transducer water level data in this report are for monitoring wells TW-1, TW-2, TW-3, TW-4, TW-8, Deep Test (DT) 5a, DT-9, and DT-10. These wells have been used to monitor the regional aquifer at LANL for over 40 years.

We present the transducer water level data and the manual water level measurements that were obtained in the test wells from 1992 to 2003. Manual water level measurements provide the datum and validation for transducer measurements. There are periods of transducer data for which manual measurements are not available: these transducer data may be shown on time-series graphs to demonstrate the relative water level changes during the period, but an absolute water level cannot be assigned to these data. In addition, there are periods of transducer data that document slippage of the transducer cable or other transducer malfunctions that render the resulting data ambiguous. We present transducer data that we judge to be invalid because of data collection issues to provide guidance for improving transducer water level measurement methods.

For the 11-year period that transducers have been used to measure water level in the test wells, the largest fluctuation in water level has been in TW-1, where the water level increased about 55 ft between 1997 and 2000. The water level rise in TW-1 ended in 2000, beginning a steep decline. By 2003, the water level in TW-1 declined to within 10 ft of the 1992 water level; a groundwater mound is apparently present beneath Pueblo Canyon at TW-1. The groundwater mound near TW-1 is likely due to infiltration of runoff and effluent from the Los Alamos County sanitary treatment plant in Pueblo Canyon.

The water level in TW-2 declined about 8.7 ft from 1992 to 2000. TW-2 experienced an apparent transducer failure in late 2000, thus transducer water level data since that time are shown for information purposes only because a reference level is not available. TW-3 shows a relatively steady water level decline from 1992 to 1997; from 1992 to 2001, the water level in TW-3 declined about 8 ft. Water level data obtained from TW-3 since 2001 indicate a malfunction of the transducer equipment and require further evaluation.

TW-4 has the highest water elevation of the test wells and since 2000 shows a gradual decline of about 1 ft. The fluctuation in transducer water level measured from 1993 to 1996 is not consistent with manual water level measurements, and we consider these data invalid. From 1992 to 2003, TW-8 has shown a gradual water level decline of about 7 ft, most of which appears to have occurred before 2000. The three deep test wells at Technical Area 49 show an average water level decline of about 3 ft from 1992 to 2003.

We present the annual rates of water level decline in the test wells for the overall period since the wells were drilled, and for the period 1992 to 2003. Water level decline is greatest for wells located nearest to water supply production. Beginning when the wells were drilled in the 1950s or 1960s, the annual rates of water level decline range from 0.22 to 0.80 ft/yr, except for TW-1, which has an increasing water level at a rate of 1.22 ft/yr. The rates of water level decline appear to have increased for the period 1992 to 2003 in TW-2, TW-3, and DT-10, where the annual rates of decline for this period increased to 1.09, 0.84, and 0.36 ft/yr, respectively. The groundwater level declines probably result from development of a regional cone of depression caused by groundwater withdrawals from the three Los Alamos well fields.

1.0 Introduction

This report provides manual and transducer water level data for regional aquifer monitoring wells (test wells or TW) TW-1, TW-2, TW-3, TW-4, TW-8, Deep Test (DT) 5a, DT-9, and DT-10. Table 1 lists location, elevation, and depth data for the test wells, and Figure 1 shows the locations of the test wells and other regional aquifer wells at Los Alamos National Laboratory (LANL). Well construction information for the test wells is provided by Purtymun (1995).

Table 1. Test Wells at Los Alamos National Laboratory

Well	Location	Date Completed	Total Depth (ft)	X-Coord (ft)	Y-Coord (ft)	Surface Elevation (ft)
TW-1	Pueblo Canyon	Jan-50	642	1,650,041.5	1,772,076.9	6369.2
TW-2	Pueblo Canyon	Nov-49	834	1,634,231.1	1,777,267.9	6647.6
TW-3	Los Alamos Canyon	Nov-49	815	1,637,727.5	1,773,138.1	6595.3
TW-4	Pueblo Canyon	Mar-50	1205	1,624,028.1	1,777,680.1	7244.6
TW-8	Mortandad Canyon	Dec-60	1065	1,632,573.9	1,769,506.6	6873.5
DT-5A	Frijoles Mesa	Jan-60	1821	1,625,310.0	1,754,789.4	7143.9
DT-9	Frijoles Mesa	Feb-60	1501	1,628,993.6	1,751,492.6	6935.0
DT-10	Frijoles Mesa	Mar-60	1409	1,628,988.5	1,754,448.8	7019.9

Source: LANL Water Quality and Hydrology group (RRES-WQH) Water Quality Database (WQDB), Purtymun (1995), Koch and Rogers (2003); and LANL (1997). The coordinate system is NM State Plane, North American Datum of 1983 (NAD-83).

Transducers were initially installed in the test wells in 1992 and 1993 (EPG 1994); transducer water level data have been obtained at intervals since that time. Initially, transducer water level data were obtained hourly from the test wells, but since about 1999, transducer water level data were usually obtained once every three hours. Transducer data have been recorded in test wells at smaller time intervals for special projects such as aquifer testing of nearby water supply wells, such as the pumping test at supply well O-4 in 1993 (Purtymun et al. 1995). Some transducer water level data have previously been reported in Environmental Surveillance Reports (EPG 1994, 1995, 1996a, b), water supply reports (e.g., Purtymun et al. 1995; McLin et al. 1998; Koch and Rogers 2003), and water level data have been provided in other reports (e.g., Purtymun 1995; McLin 1996).

Before 1992, water level data for the test wells were obtained through occasional, usually annual, manual water level measurements. These water level data have been previously reported in water supply reports. This report includes the manual water level measurements obtained since 1992 during installation of transducers or pumps. The manual water level provides a reference datum for the transducer water level data.

At times, transducers were not installed, transducer or power failures occurred, or recording devices failed to properly record the data. Thus, continuous transducer water level data for the test wells are not available. This report provides the manual water level measurements obtained for test wells from 1992 to 2003 and the available transducer water level data and discusses data quality issues with the transducer data.

1.1 Transducer Procedures

Before a transducer is installed in a well, manual water level measurements (depth to water [DTW]) were usually obtained and recorded in a field logbook by RRES-WQH personnel. The manual water level measurement was obtained by lowering a graduated measuring tape attached to a weighted sounder inside the well casing to determine the DTW from the measuring point (usually measured from the top of casing). The ground elevation, the elevation of the measuring point, the DTW measurement, and other information pertinent to the manual water level measurement were documented in the field logbooks. Figure 2 shows the water level measurement parameters in a well.

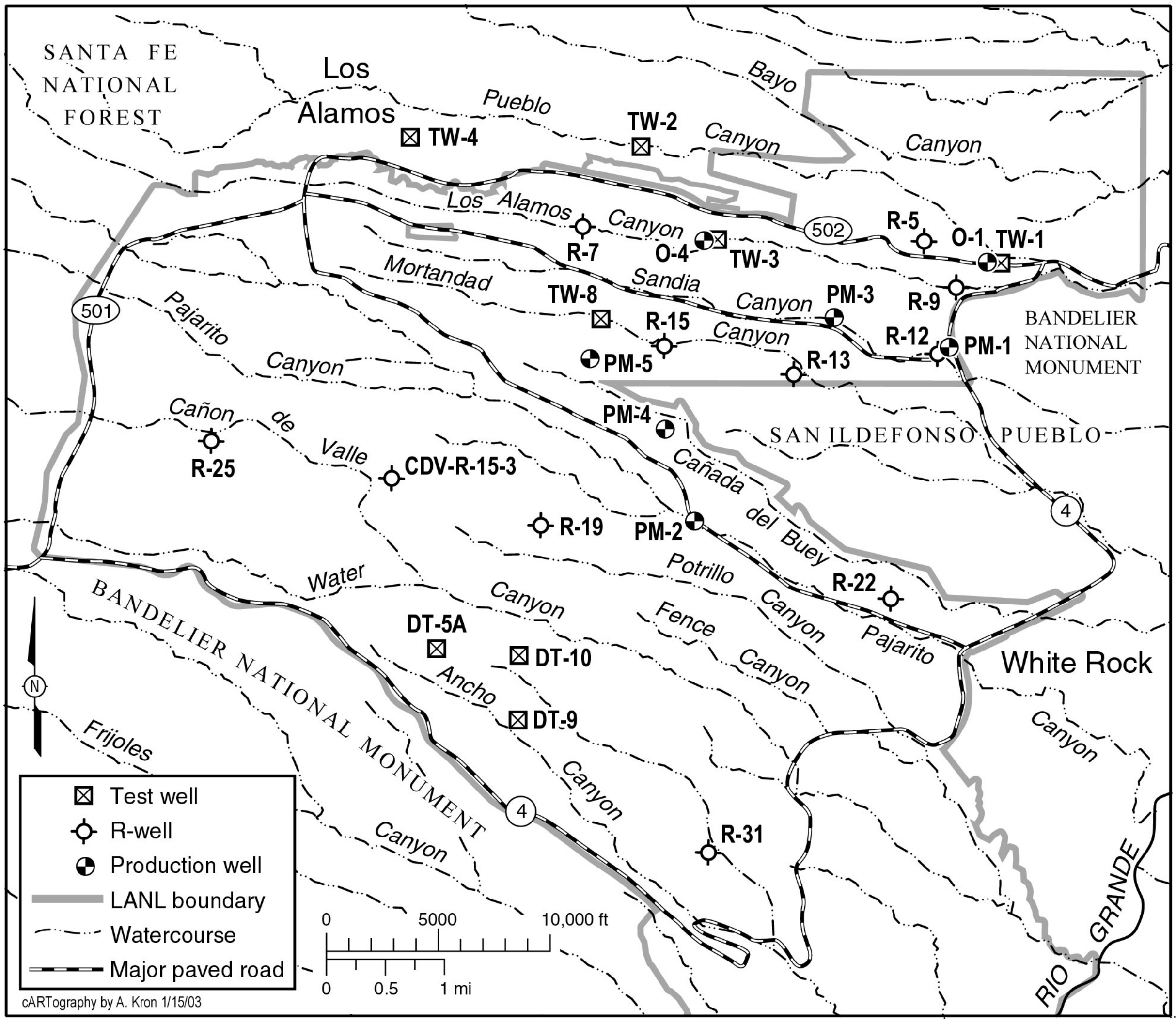

Figure 1. Water supply and monitoring wells at Los Alamos National Laboratory.

The elevation of the water in the well was calculated using the ground elevation of the well, the height of the measuring point above the ground elevation, and the DTW measurement. The water elevation at the time of transducer installation was used as the “Reference Level,” which was entered into the transducer software at the time of installation of the transducer. The reference level provides the starting elevation for the transducer software to calculate water elevation from subsequent pressure measurements. Pressure head (units of length) is the height of water in a well above the transducer that can be supported by the measured pressure. The measured pressure is expressed in pounds per square inch (psi), while pressure head is usually measured in feet of water above the transducer. Transducers have pressure ratings assigned by the manufacturer that range from 15 to 500 psi. The pressure rating of the transducer is the range of pressures, from zero psi to the pressure rating, under which the transducer is capable of accurate measurements. Under usual temperatures, pressures, and densities of water, the approximate function of water with regard to pressure is 2.31 ft/psi. Therefore, a transducer rated at 15 psi is capable of recording water depths up to approximately 34.6 ft, and a transducer rated at 100 psi is capable of measuring water depths up to about 231 ft.

The transducers were installed in each well at an appropriate depth below the surface of the water in order to record the expected range of water level fluctuations. Monitoring wells at LANL typically have shown a maximum of 25 ft of water level fluctuation over a decade (Koch and Rogers 2003, Rogers, et

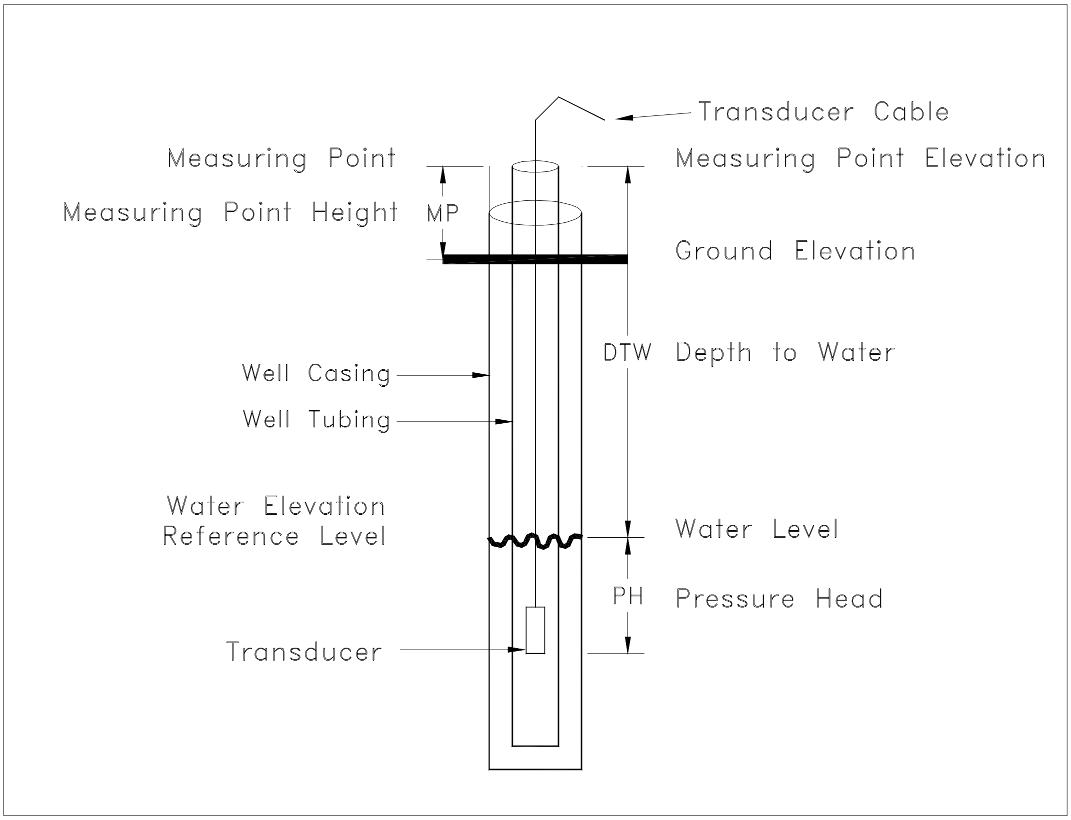

Figure 2. Schematic drawing of well showing water level measurement parameters.

al. 1996), and annual fluctuations are usually about 1 ft. A transducer rated at 15 psi was usually installed at a depth of 10 to 20 ft below the surface of the water in the test wells, within the pressure range of the transducers.

The water level in TW-1 has fluctuated up to about 60 ft, significantly greater than the other test wells, and fluctuations in some water supply wells (which are not the subject of this report) may be up to 150 to 200 ft each day (Koch and Rogers 2003). In wells like these, a transducer of adequate pressure rating was installed at a depth sufficient to measure the entire range of water level fluctuation. For example, a transducer installed at a depth of 250 ft below the nonpumping water level in a supply well would be subject to pressures up to 108 psi, and would therefore require a pressure rating greater than 108 psi to accurately measure the range of water level. Sensitivity of the transducer to small fluctuations in water level decreases as the psi rating increases, thus the lowest pressure rating possible was used for the test well transducers.

The transducer cable was secured at the surface of each well to prevent slippage. The cable was marked with tape or permanent marker at the surface to provide a reference for determining that the cable had not moved. Cable stretch may occur within the first day or so after installation of a transducer, so pressure measurements were usually programmed to begin the day after installation of the transducer, but not in all cases. By starting transducer measurements after most of the stretch occurs, the measurements more closely represent the water level in the wells. Cable stretch is apparent in some of the transducer records as seen in graphs in the following sections.

After installation of the transducer, pressure measurements were monitored for a short time via a laptop computer to ascertain that pressure measurements were stable and represented the appropriate depth below the surface of the water where the transducer was installed. At this time, the manual water elevation was entered into the transducer software as the reference level.

The transducer measures pressure in psi, from which the transducer software calculates pressure head and water elevation using site-specific variables, which include water density and the reference level. For calculations at LANL, either 0.998 or 0.999 g/cc was used as the water density, depending on the water temperature.

The manual water level measurements are an important part of collecting transducer water level data. When transducers are moved or replaced, the water depth above the transducer changes. The transducer software must be reset to reflect the most recent water elevation information. However, a manual water level was not always measured when transducers were moved or replaced because some well installations do not allow manual water level to be measured when the transducer is deployed. In some cases, the last available transducer water elevation was used as the reference level for the next series of transducer measurements. This method can usually be used when there is a short time period between the last transducer pressure data and the installation of the new transducer, assuming no malfunction of the transducer equipment during the previous installation. Where available, the next manual water level measurement was used to evaluate the preceding transducer water level data. For transducer installations that do not have good prior water level data or subsequent manual water level measurements, the reference datum for the transducer data cannot be determined. Where manual water level measurements are not available, transducer water level data may be shown on graphs to depict the character of water level fluctuations, but the water elevation cannot be derived from transducer data without manual water level measurements.

The transducers used in the test wells were manufactured by In-Situ, Inc., of Laramie, Wyoming. Additional information about the transducers is available from In-Situ, Inc., or from their web site at http://www.in-situ.com/. The use of these transducers does not constitute an endorsement of In-Situ, Inc., by LANL, the University of California, the US Department of Energy, or the US Government. The raw transducer water level data were recorded in binary formats that are proprietary to the transducer manufacturer. The raw water-level pressure data are stored in binary format in data loggers at each well and are retrieved periodically by RRES-WQH personnel. These binary files were converted to text or spreadsheet formats using the manufacturer's proprietary software, which is available on the web site.

1.2 Introduced Error

When the DTW is manually measured in a well, the DTW is determined by lowering a water sensor attached to a graduated measuring tape inside the well casing. The water sensor generates an audible tone when water is contacted by the sensor. The measuring tape is lowered and lifted several times until the depth at which the audible tone is heard stabilizes. Measurement tapes have a resolution of 0.01 ft, which can provide accurate measurements to 0.005 ft. In a deep well (greater than 500 feet), contact of the tape with the casing wall causes friction during measurement of the water level. The measuring tape may stretch while the surface of the water is being located due to the weight of the sounder and the friction, and if stored improperly. These factors introduce error into the DTW measurement.

Measurement tapes have accuracy values ranging from 0.01 ft in 100 ft (0.01%) for steel tapes to 0.04 ft in 100 ft (0.04%) for polyethylene tapes (Geotech 1994). This implies a 0.1 ft stretch for manual water depth measurements at a water depth of 1000 ft using a steel tape. Most of the manual measurements in this report since 1992 were obtained with water level measurement tapes manufactured by Solinst Canada Ltd of Georgetown, Ontario. The tape consists of two wires that conduct the electrical signal, which are embedded in a polyethylene strip. Newer versions of this water level meter include several strands of stainless steel wire within the polyethylene strip, intended to minimize the amount of stretch (http://www.solinst.com/Prod/101/101WaterLevelMeters.html).

When a new transducer cable is installed in a deep well such as in the test wells, some stretching of the cable occurs in the first few days, which lowers the transducer in the well and causes higher apparent pressure head values and water level values. The effect of cable stretch is noted in some of the following water level figures, and for transducer installations of about 1000 ft, the cable stretch can represent up to about 0.3 ft of apparently higher water levels immediately after transducer installation. However, one cannot be certain that higher water level data after transducer installation are due to cable stretch or to an actual rise in water level until the transducer water level data are evaluated with regard to subsequent manual water level measurements. The effect of cable stretch was usually minimized by programming transducer measurements to begin one day after installation of a new transducer cable, which can be done when the water level is not expected to change significantly.

2.0 Test Well Water Level Data

We present the transducer water level data and the manual water level measurements that were obtained from 1992 to 2003. Manual water level measurements provide the datum and validation for transducer measurements. There are periods of transducer data for which manual measurements are not available, so these data may be shown on time-series graphs to demonstrate the relative water level changes during the period, but an absolute water level cannot be assigned to the data. In addition, there are periods of transducer data that document slippage of the cable, which renders the resulting data ambiguous. We present transducer data that we judge to be invalid because of data collection issues to provide guidance for improving transducer water level measurement methods.

The water level data presented in this report and stored in the WQDB are not the raw water level data. We examined the raw data and revised reference levels based on corrected surface elevation and measuring point height data, and when manually measured water levels were not available for a transducer installation period, we revised the reference level for that data set based on the most recent previous transducer data, etc. From 1992 to about 1999, most transducer data were recorded on an hourly basis, but since 1999, most data were recorded at 3-hr intervals. We decreased measurement frequency from several daily measurements to one daily value for presentation in graphs and storage in the WQDB.

Transducer data may show variation in water level arising from several sources. Both atmospheric fronts and daily temperature changes cause fluctuation in local barometric pressure, leading to changes in water levels on a daily (up to about 0.2 ft) or weekly basis (up to about 0.5 ft). Seasonal variations in recharge or water supply pumping might affect water levels on a seasonal time scale. Long-term effects of water supply pumping or recharge could cause water level changes over a period of years (Freeze and Cherry 1979). Pumping, purging, and sampling of the test wells also affected water levels.

Sometimes the transducer was removed during water quality sampling, so no data exist for some sampling periods, and sometimes pumping and purging for sampling caused a short-duration decrease in water level that is observed in the water level data. At times, transducer water level data became unusable due to data corruption, which usually occurred when the transducer and/or data logger became compromised due to water intrusion or corrosion, or due to failure of the equipment. The strain gauge sensors occasionally failed or lost calibration causing inaccurate pressure measurements. This rendered the resulting water level data useless. For this reason, periodic inspection of the transducer equipment and regular manual water level measurements are an important quality control step for transducer water level measurements.

Each test well has its own history of manual water level measurements and transducer water level measurements, which are discussed in following sections. The water level data are also available on the RRES-WQH database, which is accessible on the Internet at http://wqdbworld.lanl.gov.

2.1 TW-1

A transducer was first installed in TW-1 on October 23, 1992; several periods of transducer data are available that extend into 2003. Figure 3 shows the time series of transducer water level data for TW-1 and the manually measured water level. Table 2 lists the periods of transducer water level data and provides pertinent information about the water level data. There have been periods when no data were collected. Table 3 lists the manual water elevations from TW-1 since 1992.

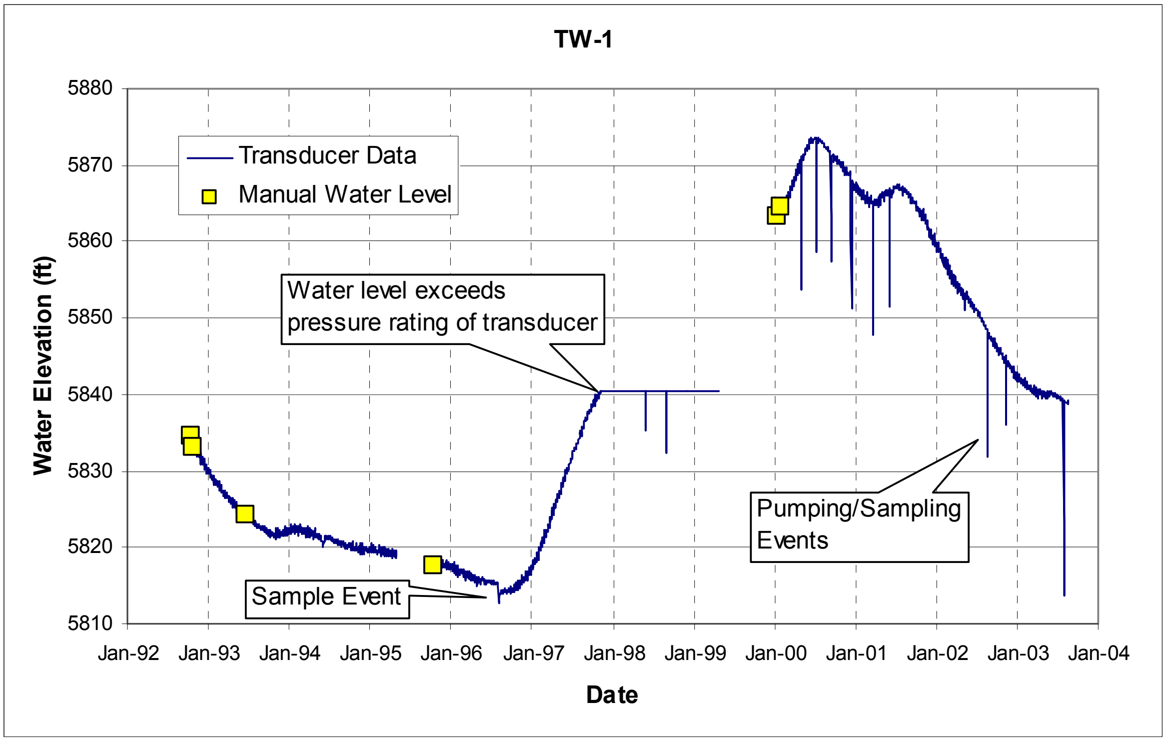

Figure 3. Water level in TW-1.

Table 2. TW-1 Transducer Data Periods, 1992–2003

Well	Start Date	End Date	Comment
TW-1	10/24/92	06/17/93	Initial transducer installation
TW-1	06/19/93	04/28/95	Reinstall transducer
TW-1	10/14/95	01/18/96	Water level begins rising in late 1996, 20 psi transducer
TW-1	01/19/96	10/23/97	Pressure Head exceeded rated capacity 10/20/1997
TW-1	10/23/97	04/28/99	Transducer incompetence due to over pressurization
TW-1	01/12/00	01/26/00	Install new 100 psi transducer
TW-1	01/27/00	12/18/00	Reinstall transducer
TW-1	12/20/00	06/11/01	Firmware upgrade 6/11/01
TW-1	06/12/01	06/28/01	Retrieve data, restart transducer software and data logger
TW-1	06/29/01	07/01/02	Retrieve data, restart transducer software and data logger
TW-1	07/02/02	08/19/03	Most recent download of transducer data

Table 3. TW-1 Manual Measurements

Well	Date	Elevation (ft)	Comment
TW-1	10/13/92	5834.39	
TW-1	10/23/92	5833.11	Install transducer
TW-1	06/17/93	5824.23	Reinstall transducer
TW-1	10/13/95	5817.73	lowered transducer due to lower water level
TW-1	01/11/00	5863.34	Install new 100 psi transducer
TW-1	01/26/00	5864.50	Reinstall transducer

The water level in TW-1 declined from 1992 to the middle part of 1996. The transducer was lowered in the well in October 1995 to accommodate the falling water level. The water level in TW-1 was lowest in September 1996 (5814 ft amsl) after a groundwater sampling event. The water level began to rise in October 1996 and rose sharply in 1997 to an elevation of about 5840 ft on October 23, 1997, an increase of 26 ft in one year. Due to the rising water level, the pressure head on the 20 psi transducer that was installed in October 1995 was exceeded on October 23, 1997. At the depth of installation, the transducer was not capable of recording water levels higher than 5840.4 ft, thus transducer data from October 23, 1997, to April 28, 1999, when the record ends, are invalid because pressure head was greater than the rated capacity of the transducer and the transducer obviously did not record characteristic water level data (see Figure 3). The water level was apparently below 5840.4 ft at times between October 23, 1997, and November 7, 1997, and on May 28, 1999, and August 31, 1999 (during pumping/sampling events), when the transducer may have accurately recorded the water level (see Figure 3). Thus, it appears that the transducer did not fail during the over-pressurization period, but was not able to record accurate water levels above the rated capacity.

A new transducer rated at 100 psi was installed in TW-1 in January 2000 when the water level was about 5864 ft amsl. The water level continued to rise in TW-1 in early 2000 until June 30, 2000, when the peak water level was 5873.7 ft amsl. The total increase in water level from 1996 to 2000 was about 60 ft. Beginning In July 2000, the water level in TW-1 declined until April 2001 when the water level increased about 2 ft during May and June 2001. The water level began to decline in July 2001 and continued to decline through August 2003, when data were last obtained from the well. When the pump in TW-1 is operated for collection of groundwater samples, the water level declines 15 to 25 ft for a short time; these short-term water level declines are shown in Figure 3.

Figure 4 shows the chloride and nitrate (as nitrogen) concentration histories for groundwater samples collected from TW-1, along with the water level history since 1950. Between 1965 and 1989, no water level measurements were obtained. Prior to 1981, the nitrate (nitrate as nitrogen) concentration of groundwater samples collected from TW-1 averaged 3.3 mg/L; subsequent samples have averaged about 6.8 mg/L, a significant increase from pre-1980 concentrations. Chloride concentrations averaged 4.7 mg/L before 1981 and 33.6 mg/L since that time (ESP 2002, p. 203).

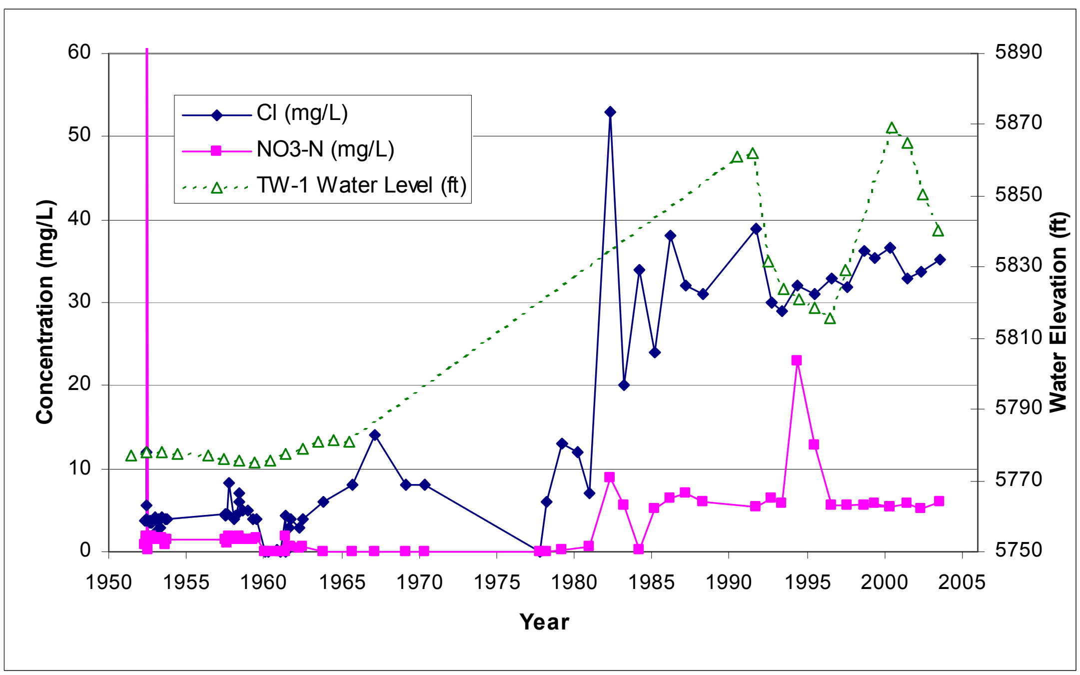

Figure 4. Long-term nitrate (as nitrogen) and chloride history compared with annual water level history for TW-1.

Data Source: Nitrate and Chloride data: WQDB (2003), ESP (2002); Water level data: Koch and Rogers (2003) and this report.

In about 1980, the Los Alamos County Bayo sanitary wastewater treatment plant, which discharges into Pueblo Canyon upstream of TW-1, greatly increased discharges (Glasco 2000). This increase in flow and infiltration apparently resulted in the higher values of nitrate and chloride in TW-1 beginning about 1981. The increased infiltration probably created a groundwater mound in the regional aquifer beneath this section of the canyon, indicated by the water level rise in TW-1. Temporal variations in effluent release and the amount of runoff in the canyon have likely caused variation in infiltration and water level in TW-1 during this period.

2.2 TW-2

A transducer was installed in TW-2 on June 16, 1993, when the water elevation was 5856.0 ft amsl; several periods of transducer data are available that extend into 2003. Figure 5 shows the time series of transducer water elevation data for TW-2 and the manually measured water elevations. Table 4 lists the periods of transducer water level data and provides pertinent information about the water level data. There have been periods when no data were collected. Table 5 lists the manual water elevations that have been obtained from TW-2 since 1992.

From June 1993 to February 1994, the water level in TW-2 declined gradually to about 5854 ft amsl. A sudden decline of about 1.2 ft from February 13, 1994, to April 15, 1994, was likely related to a transducer failure; the transducer data after this time until early 1996 show relative trends, but the absolute depths are not reliable (Figure 5).

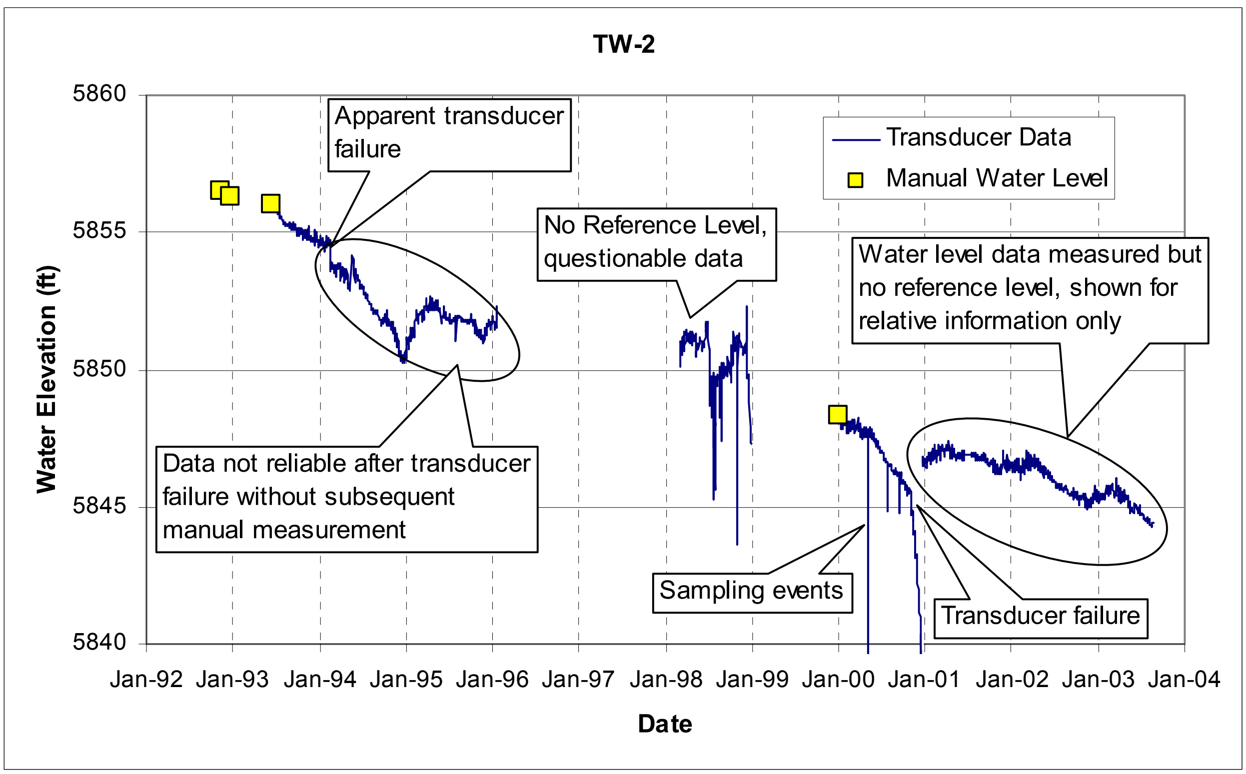

Figure 5. Water level in TW-2.

Table 4. TW-2 Transducer Data Periods, 1992–2003

Well	Start Date	End Date	Comment
TW-2	06/19/93	01/18/96	Apparent transducer failure 2/12/94
TW-2	03/01/98	12/31/98	No reference level, abnormal end to data set, questionable data
TW-2	01/05/00	12/18/00	New transducer, failed circa 10/30/00
TW-2	12/19/00	06/14/01	New transducer, no viable reference level
TW-2	07/12/01	07/01/02	Installed after pump removal and repair
TW-2	07/02/02	08/19/03	Firmware upgrade 7/1/02

Table 5. TW-2 Manual Measurements

Well	Date	Elevation (ft)	Comment
TW-2	11/09/92	5856.52	Plan transducer installation
TW-2	12/21/92	5856.27	Install transducer (no data)
TW-2	06/16/93	5856.03	Install transducer
TW-2	01/05/00	5848.33	Install new transducer

A new transducer was installed in TW-2 on February 28, 1998, however, no reference level is available for this transducer installation. The transducer data extend until December 31, 1998, and show uncharacteristic water level changes due to operating the pump at times in an effort to collect groundwater samples. A pump test was performed in October 1998 but the well did not produce adequate water and the water level fell below the level of the pump. The 1998 transducer data are shown on Figure 5 for information purposes but without a reference level, the data are not valid.

Another new transducer was installed in TW-2 on January 5, 2000, when the measured water level was 5848.3 ft amsl. The water level in 2000 declined to about 5846 ft in October 2000. From October 30, 2000, to December 18, 2000, the water level in TW-2 exhibits a decrease of more than 7 ft. The decrease cannot be explained by supply well pumping or groundwater sampling. We attribute this 7-ft decline in water level to transducer failure. A new transducer was installed on December 18, 2000, but a manual water level measurement was not obtained; the reference level used for display of the transducer data on Figure 5 after December 18, 2000, was 5846.5 ft amsl, which is the arbitrary reference level for the subsequent measurements obtained through 2001, 2002, and 2003. The water level measurements after December 18, 2000, have no reference datum, although the data are shown in Figure 5 to exhibit the relative fluctuations in water level for this period. The data indicate that from December 18, 2000, to August 19, 2003, the water level in TW-2 declined about 2 ft.

The transducer was removed from TW-2 on June 14, 2001, so the pump could be repaired. The transducer was reinstalled on July 12, 2001, when the reference level was again set using the last transducer water level obtained on June 14, 2001. No manual measurements of water depth were obtained at this time.

2.3 TW-3

A transducer was installed in TW-3 on August 4, 1992, when the water elevation was 5820.1 ft amsl. The transducer equipment did not work properly and another transducer was installed on October 8, 1992, when the water elevation was 5819.8 ft amsl. TW-3 was used as an observation well for pumping tests at supply well O-4 February 24 to March 18, 1993, and PM-3 March 25 to April 2, 1993 (Purtymun et al. 1995, p. 17). The water level in TW-3 declined about 0.5 ft in response to pumping at O-4. The transducer was removed from TW-3 after the PM-3 pump test. During an aquifer test of O-4 in 1989, TW-3 showed no drawdown (Stoker et al. 1992).

A new transducer was installed in TW-3 on January 14, 1994, and transducer water level data extend into 1997. Figure 6 shows the time series of average daily transducer water level data for TW-3 and the manually measured water elevations. Table 6 lists the periods of transducer water level data and provides pertinent information about the water level data. There have been periods when no data were collected. Table 7 lists the manual water elevations that have been obtained from TW-3 since 1992.

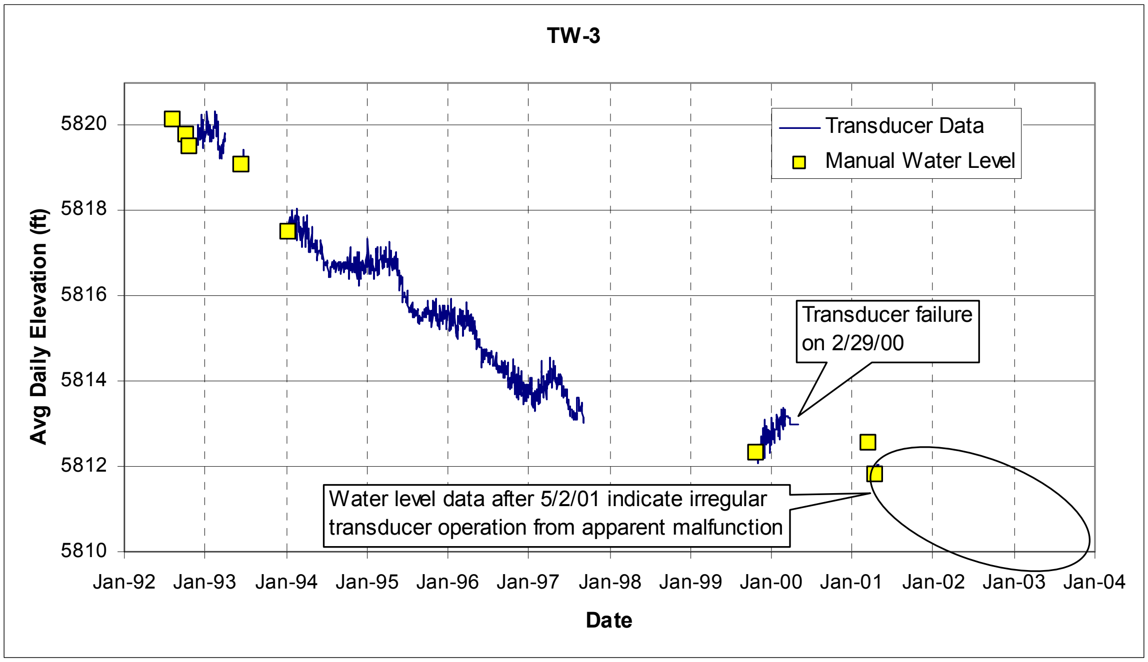

Figure 6. Water level in TW-3.

Table 6. TW-3 Transducer Data Periods, 1992–2003

Well	Start Date	End Date	Comment
TW-3	08/05/92	10/08/92	Install Data Pod transducer, did not record data properly
TW-3	10/08/92	10/23/92	Install In-Situ transducer, no data
TW-3	10/23/92	04/02/93	Reinstall transducer, data file begins 11/25/92
TW-3	06/19/93	06/27/93	Reinstall transducer, only 8 days of data due to water leak
TW-3	01/14/94	01/22/96	New transducer, downloaded data on1/22/96
TW-3	01/22/96	09/04/97	Same transducer as previous series
TW-3	10/28/99	05/02/00	New transducer, equipment failure 2/29/00
TW-3	04/18/01	08/20/03	New transducer, erratic results, requires additional evaluation

Table 7. TW-3 Manual Measurements

Well	Date	Elevation (ft)	Comment
TW-3	08/04/92	5820.14	Install transducer, failed to operate
TW-3	10/08/92	5819.80	Install Transducer
TW-3	10/23/92	5819.52	Reset transducer
TW-3	06/15/93	5819.08	Reinstall Transducer
TW-3	01/13/94	5817.52	Install new transducer
TW-3	10/27/99	5812.32	Install new transducer
TW-3	03/14/01	5812.55	Install new transducer, failed to work
TW-3	4/17/01	5811.81	Install new transducer

From 1992 to 2001, the water level in TW-3 declined about 8 ft. The data indicate that most water level declines occur during summer months and that stable to slightly increasing water level occurred during winter months. Nearby supply well O-4 began production in 1993 and is primarily used during the summer months.

A new transducer was installed in TW-3 on October 27, 1999, when the water level was 5812.3 ft amsl. The water level rose slightly through the winter to about 5813.1 ft amsl on February 29, 2000. Beginning at 18:00 on February 29 until the end of the transducer data file on May 2, 2000, the water level data are uncharacteristically constant (see Figure 6), indicating a failure of the transducer equipment. The 0.8 ft rise in water level before the transducer failure is also uncharacteristic when compared with other data from TW-3 and may be unreliable transducer data.

Another new transducer was installed in TW-3 on April 17, 2001, when the water level was 5811.8 ft amsl. The transducer apparently malfunctioned on May 2, 2001, when the water level was 5812.0 ft amsl. Transducer data after that time show apparent recurring failure of the transducer equipment to properly measure the pressure head. Additional water level measurements of TW-3 and further evaluation of the data from May 2, 2001, to August 20, 2003, are needed to determine if any valid data can be recovered from the transducer measurements.

2.4 TW-4

A transducer was initially installed in TW-4 on June 16, 1993, when the water level was 6071.9 ft amsl. The transducer water level time series and manual measurements from TW-4 are shown in Figure 7. The periods of transducer water level data are listed in Table 8 and the manual water level measurements are shown in Table 9.

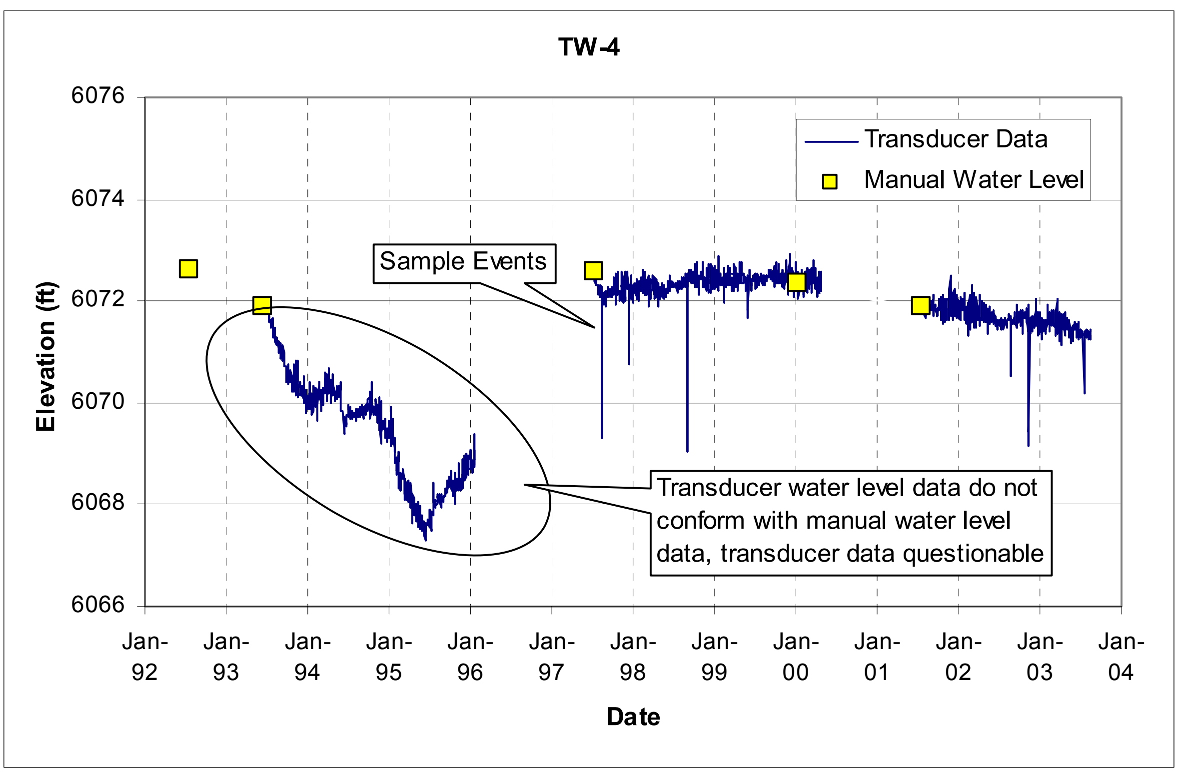

Figure 7. Water level in TW-4.

Table 8. TW-4 Transducer Data Periods, 1993–2003

Well	Start Date	End Date	Comment
TW-4	06/19/93	01/22/96	Initial transducer data, water level trends questionable
TW-4	07/08/97	01/07/00	Install new transducer
TW-4	01/08/00	04/26/00	Install new transducer
TW-4	07/20/01	08/07/02	Install new transducer, download data on 8/7/02
TW-4	08/08/02	08/19/03	Same transducer as previous series

Table 9. TW-4 Manual Measurements

Well	Date	Elevation (ft)	Comment
TW-4	07/20/92	6072.56	Purtymun 1995, p. 223
TW-4	06/16/93	6071.88	Install transducer
TW-4	07/07/97	6072.58	Poor documentation of water level measurement
TW-4	01/07/00	6072.35	Install new transducer
TW-4	07/20/01	6071.90	Install new transducer

All manual water level measurements in TW-4 have been within 1 ft of 6072 ft amsl. The transducer water level data for the period June 19, 1993, through January 22, 1996, show a maximum decline in water level of about 4.5 ft, which is not consistent with other water level measurements in TW-4. Calibration constants were required inputs into the data logging software in 1993; it is possible that a calibration value was incorrectly entered at the beginning of the transducer water level data collection period, which would render the data from June 19, 1993, through January 22, 1996, inaccurate and invalid.

Transducer data obtained since July 18, 1997, are relatively stable, typically ranging from 6071 to 6072.5 ft amsl. Temporary lower water level is observed during and shortly after sampling events in 2002 and 2003. The most recent average daily transducer water level in TW-4 was 6071.4 ft amsl on August 19, 2003.

2.5 TW-8

A transducer was first installed in TW-8 on October 9, 1992, when the water level was 5882.31 ft amsl. Problems occurred with the transducer installation and another transducer was installed on October 23, 1992, when the water level was 5881.89 ft amsl. The transducer was reinstalled on June 15, 1993, when the water level was 5880.97 ft amsl. Available transducer data begin June 19, 1993, and periodically extend into 2003. The transducer water level time series and manual measurements from TW-8 are shown in Figure 8. The periods of transducer water level data are listed in Table 10 and the manual water level measurements are shown in Table 11.

A submersible pump was installed in TW-8 in November 1993 and the transducer was reinstalled on December 6, 1993, when the water level was 5880.65 ft amsl. A new transducer was installed on January 10, 1994, when the water level was 5880.76 ft amsl. This transducer measured water level at least until March 31, 1997, when the data were successfully retrieved. An attempt to retrieve additional data on February 17, 1998, resulted in the discovery that the transducer data had become corrupt and records after March 1997 were lost. Transducer data are not available from TW-8 for late 1997, 1998, and 1999.

A new transducer was installed in TW-8 on January 7, 2000, when the water level was 5876.54 ft amsl. The transducer data show an uncharacteristically sharp decline in water level beginning on May 12, 2001, when the water level declined about 1.5 ft in 2 days. This event does not correlate with a

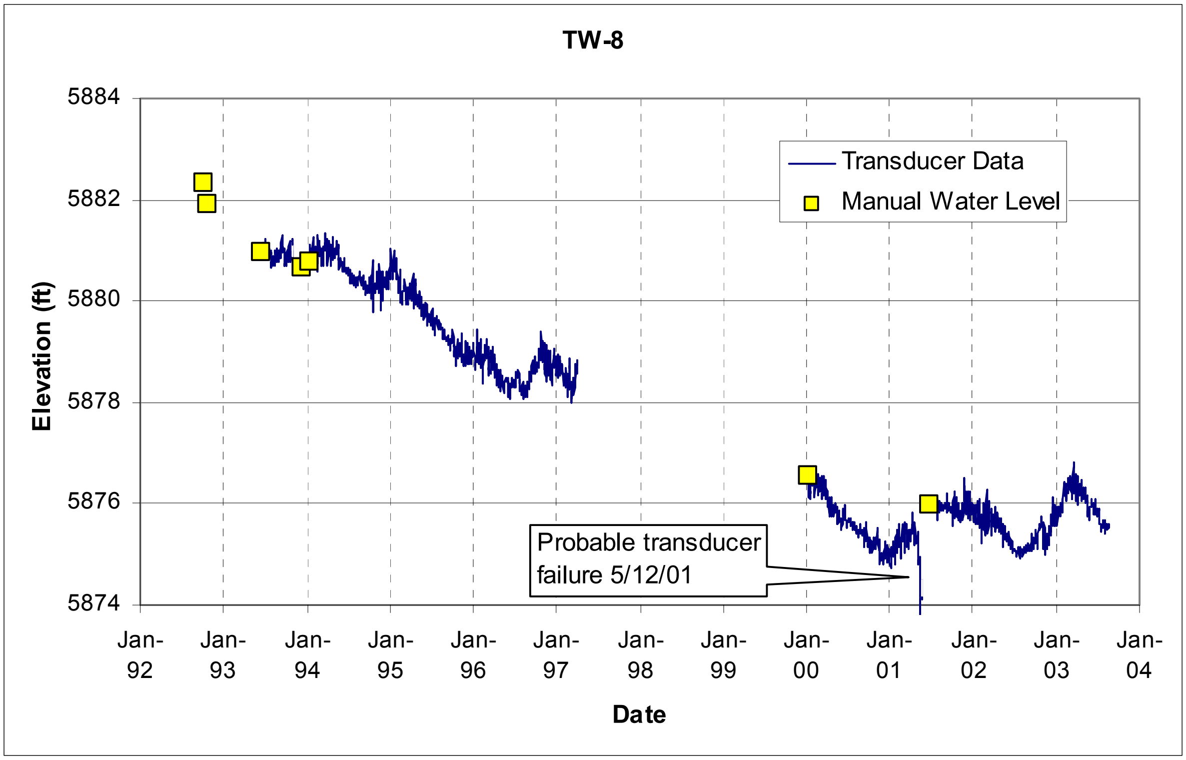

Figure 8. Water level in TW-8.

Table 10. TW-8 Transducer Data Periods, 1993–2003

Well	Start Date	End Date	Comment
TW-8	06/19/93	11/02/93	Remove transducer for pump installation November 1993
TW-8	01/11/94	11/08/94	Reinstall transducer, download data 11/08/94
TW-8	11/09/94	03/31/97	Restart measurements using same transducer
TW-8	01/08/00	11/27/00	Install new transducer, download data on 11/27/00
TW-8	11/28/00	05/25/01	Install new transducer, possible transducer failure 5/12/01
TW-8	06/29/01	07/01/02	Install new transducer, download data upgrade firmware 7/01/02
TW-8	07/02/02	08/19/03	Start measurements using existing transducer

Table 11. TW-8 Manual Measurements

Well	Date	Elevation (ft)	Comment
TW-8	10/09/92	5882.31	Install transducer, cable slipped
TW-8	10/23/92	5881.89	Reinstall transducer
TW-8	06/15/93	5880.97	Reset transducer
TW-8	12/06/93	5880.65	Install pump, reinstall transducer
TW-8	01/10/94	5880.76	Install new transducer
TW-8	01/07/00	5876.54	Install new transducer
TW-8	06/28/01	5875.96	Install new transducer

sampling event, and probably represents a failure of the transducer equipment. The transducer data came to an abnormal end on May 25, 2001, which further indicate a failure of the equipment.

A new transducer was installed on June 28, 2001, when the water level was 5875.96 ft amsl. The measurements continue until August 19, 2003, when the transducer water level was about 5875.5 ft amsl. Since January 2000, the water level data indicate an annual fluctuation of about 1 ft, but no significant decline. From 1992 to 2003, the water level in TW-8 declined about 7 ft, from near 5882 ft amsl to about 5875 ft amsl.

2.6 DT-5A

DT-5A is located at Technical Area (TA) 49 relatively close to test wells DT-9 and DT-10. A transducer was first installed in DT-5A on April 23, 1993, when the water level was 5961.51 ft amsl, however no data were recovered from the equipment. The transducer was reinstalled on June 14, 1993, when the water level was 5961.15 ft amsl. Figure 9 shows the time series of transducer water level data for DT-5A and the manually measured water level. Table 12 lists the periods of transducer water level data and Table 13 lists the manual water levels that have been obtained from DT-5A since 1993.

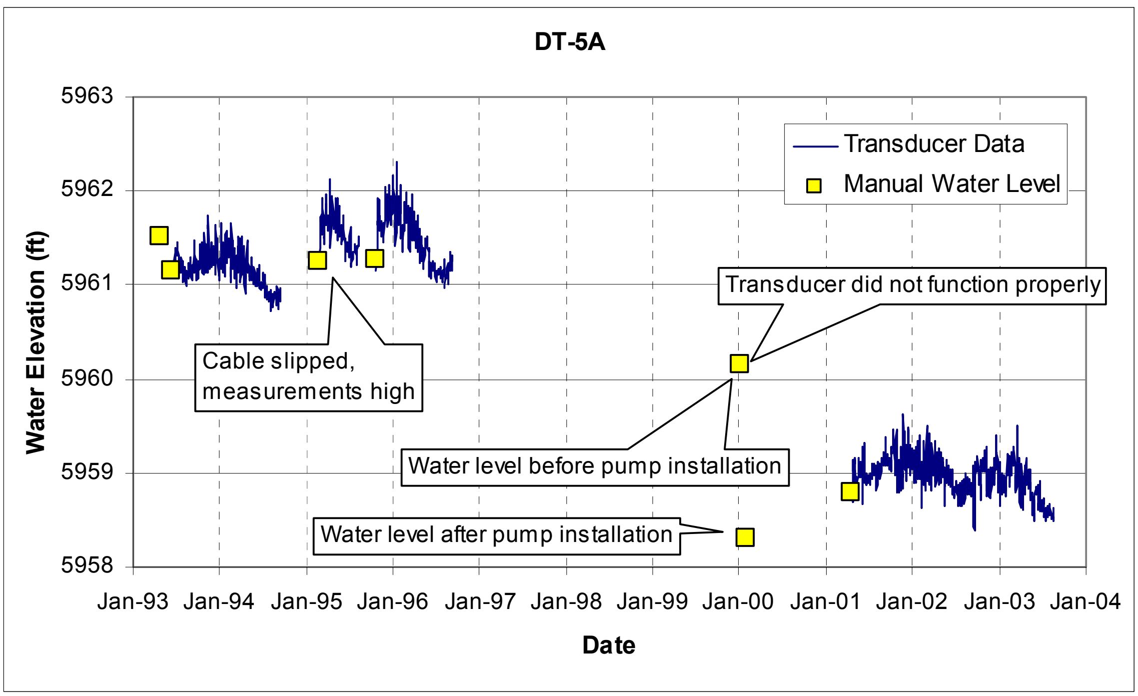

Figure 9. Water level in DT-5A.

Table 12. DT-5A Transducer Data Periods, 1993–2003

Well	Start Date	End Date	Comment
DT-5A	06/19/93	09/12/94	Initial transducer installation
DT-5A	02/24/95	08/11/95	Cable slipped, transducer measurements high
DT-5A	10/24/95	01/10/96	Reinstall transducer, probable cable slippage
DT-5A	01/11/96	09/09/96	Secure transducer cable, restart transducer measurements
DT-5A	01/07/00	01/28/00	Install new transducer, did not function properly
DT-5A	04/21/01	07/08/01	Install new transducer, download data 7/08/01
DT-5A	07/09/01	09/16/02	Download data 9/16/02, continue recording
DT-5A	09/17/02	08/18/03	Download data 8/18/03, continue recording

Table 13. DT-5A Manual Measurements

Well	Date	Elevation (ft)	Comment
DT-5A	04/23/93	5961.51	Install transducer, no data
DT-5A	06/14/93	5961.15	Reinstall transducer
DT-5A	02/23/95	5961.26	Reinstall transducer, cable slipped
DT-5A	10/20/95	5961.28	Reinstall transducer
DT-5A	01/06/00	5960.15	Install new transducer, did not operate properly
DT-5A	01/29/00	5958.31	Install new transducer after pump installation
DT-5A	04/20/01	5958.79	Install new transducer

The transducer was reinstalled on February 23, 1995, when the water level was 5961.26 ft amsl. In October 1995, it was discovered that the cable had slipped about 2 in., so the transducer was reinstalled on October 23, 1995, when the water level was 5961.28 ft amsl. Transducer data are not available from 1997 to 1999.

A new transducer was installed in DT-5A on January 6, 2000, when the water level was 5960.15 ft amsl; however the transducer was inoperative and did not function properly. A pump was installed in the well on January 28, 2000, after which another new transducer was installed on January 29, 2000, when the water level after operating the pump was 5958.31 ft amsl. This transducer was found to be malfunctioning on October 30, 2000, and was removed from the well.

Another transducer was installed in DT-5A on April 20, 2001, when the water level was 5958.79 ft amsl. This transducer has provided water level data into August 2003 that shows daily and seasonal fluctuations of less than 1 ft. On August 18, 2003, the average daily water level in DT-5A was 5958.63 ft amsl. From 1993 to 2003, the water level in DT-5A declined about 3 ft, from 5961.4 ft to 5958.6 ft amsl.

2.7 DT-9

A transducer was first installed in DT-9 on November 20, 1992, when the water level was 5920.9 ft amsl, however the equipment did not work, and another transducer was installed on November 23, 1992, when the water level was 5920.70 ft amsl. Figure 10 shows the time series of transducer water level data for DT-9 and the manually measured water levels. Table 14 lists the periods of transducer water level data and Table 15 lists the manual water level measurements that have been obtained from DT-9 since 1992.

The transducer was reinstalled on June 14, 1993, when the water level was 5920.8 ft amsl and again on February 23, 1995, when the water level was 5920.3 ft amsl. This transducer measured water levels until August 1996. Cable stretch may be responsible for slightly higher measured water level of about 0.2 ft during 1995 and 1996. A new transducer was installed in DT-9 on November 15, 1996, when the water level was 5919.5 ft amsl; this transducer measured water level until February 1, 2000.

The water level was measured before installation of a pump and new transducer in DT-9 on February 1, 2000; a pumping test was conducted on February 25, 2000. Before the pump was installed, the water level was 5918.4 ft amsl, after the pumping test the water level was 5917.70 ft amsl. The new transducer was programmed to begin measurements on February 26, 2000, but when checked in October 2000 the transducer had apparently failed and no data were obtainable from the equipment.

A new transducer was installed March 20, 2001, when the water level was 5917.95 ft amsl. Data were retrieved from this transducer on July 9, 2001, and July 2, 2002, but the transducer did not respond on August 18, 2003, when attempting to download the data.

From 1992 to 2002, the water level in DT-9 declined about 3 ft, from about 5921 ft to 5918 ft amsl.

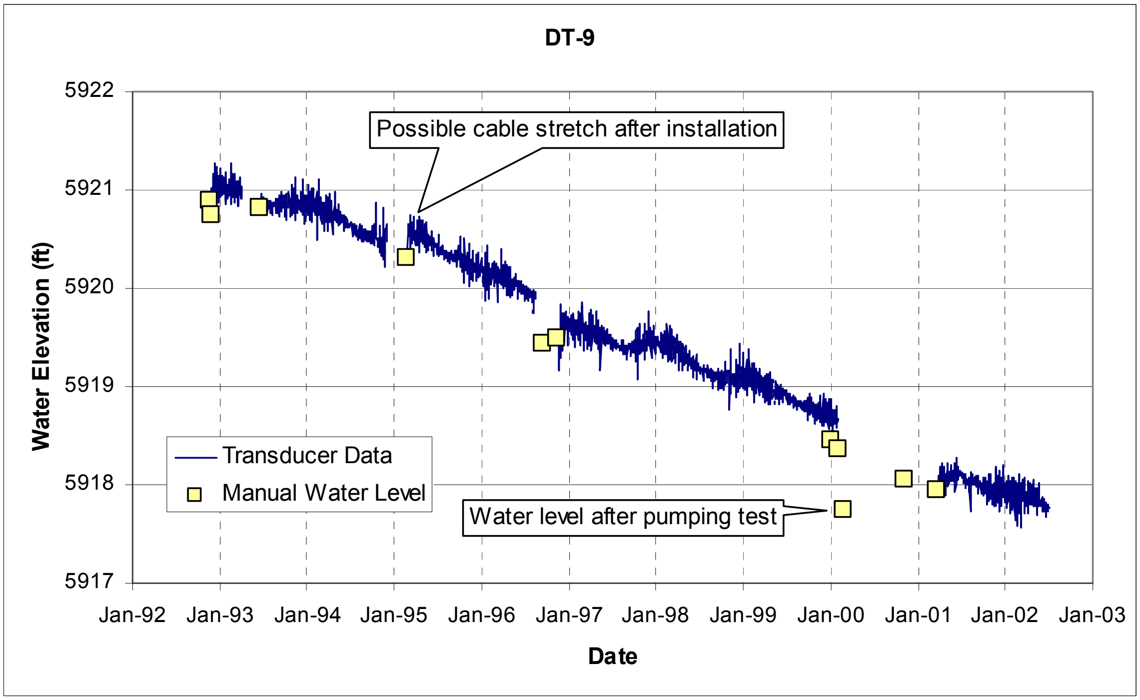

Figure 10. Water level in DT-9.

Table 14. DT-9 Transducer Data Periods, 1992–2003

Start Date	End Date	Comment
11/25/92	04/02/93	Initial transducer installation, probable cable stretch about 0.1 ft
06/19/93	11/28/94	Reinstall transducer, secure cable
02/24/95	08/11/96	Reinstall transducer, probable cable stretch about 0.2 ft
11/15/96	05/10/99	Install new transducer
05/10/99	01/06/00	Retrieve data, restart data logging
01/07/00	02/01/00	Restarted data logging, removed transducer for pump installation
02/01/00	02/25/00	Install new transducer and pump 2/01/00, pump test 2/25/00
02/26/00	10/30/00	Resume data logging, no data, removed transducer 10/30/00
03/21/01	07/09/01	Install new transducer, retrieve data 7/09/01, continue logging
07/10/01	07/02/02	Retrieve data 70/2/02, continue data logging
07/03/02	08/18/03	Attempt to download data 8/18/03, no response from transducer

Table 15. DT-9 Manual Measurements

Well	Date	Elevation (ft)	Comment
DT-9	11/20/92	5920.89	Transducer installation, did not work
DT-9	11/23/92	5920.74	Install new transducer
DT-9	06/14/93	5920.81	Measured water level and reset transducer
DT-9	02/23/95	5920.31	Measured water level and reset transducer
DT-9	09/09/96	5919.44	Water level measurement not well documented
DT-9	11/15/96	5919.49	Install new transducer
DT-9	01/06/00	5918.45	Install new transducer
DT-9	02/01/00	5918.36	Water level before pump installation
DT-9	02/25/00	5917.74	Water level after pump test
DT-9	11/03/00	5918.05	Water level after removing transducer
DT-9	03/20/01	5917.95	Install new transducer

2.8 DT-10

A transducer was first installed in DT-10 on April 9, 1993, when the water level was 5923.62 ft amsl. The transducer was reinstalled on June 14, 1993, when the water level was 5923.41 ft amsl. Figure 11 shows the time series of transducer water level data for DT-10 and the manually measured water levels. Table 16 lists the periods of transducer water level data and Table 17 lists the manual water level measurements that have been obtained from DT-10 since 1992.

Transducer data collected in 1995 show an apparent increasing water level that resulted from the cable slipping deeper into the well; these data are not valid. An apparent water level decline of about 0.5 ft between the November 1996 to January 2000 transducer data series and the series beginning in

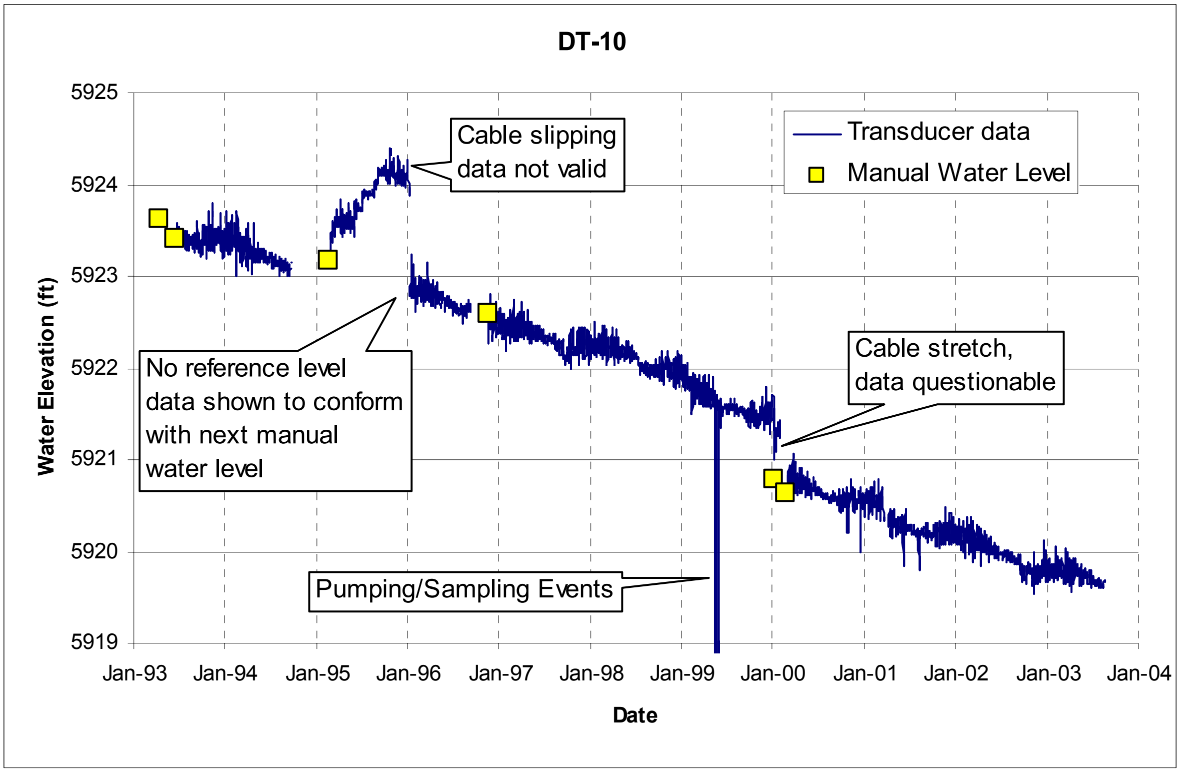

Figure 11. Water level in DT-10.

Table 16. DT-10 Transducer Data Periods, 1992–2003

Start Date	End Date	Comment
06/19/93	09/21/94	Reinstall transducer
02/24/95	01/09/96	Cable slipped, data not valid
01/10/96	09/09/96	No reference level for measurements
11/16/96	05/10/99	Install new transducer, about 2.5 years of good transducer data
05/11/99	01/06/00	Restart logging using previous transducer water level
01/07/00	02/01/00	Install new transducer, cable slipped, remove for pump installation
02/26/00	03/20/01	Reinstall transducer after pump installation
04/06/01	07/09/01	New transducer, reference level from previous data set
07/10/01	09/16/02	Install new firmware 7/09/01, reference level from previous data set
09/17/02	08/18/03	Restart logging using reference level from previous data set

Table 17. DT-10 Manual Measurements

Well	Date	Elevation (ft)	Comment
DT-10	04/09/93	5923.62	Install transducer, no transducer data available
DT-10	06/14/93	5923.41	Reset transducer
DT-10	02/23/95	5923.18	Reset transducer, higher measuring point
DT-10	11/15/96	5922.58	Install new transducer, higher measuring point
DT-10	01/06/00	5920.78	Install new transducer
DT-10	02/25/00	5920.63	Reset transducer

January/February 2000 is likely due to drift of the pressure sensor during the long transducer deployment (>3 yrs), or possibly to a change in measurement equipment in 2000. The short transducer data series in January 2000 shows apparent increasing water level resulting from cable slippage, these data are not valid.

For the 10 years from 1993 to 2003, the water level in DT-10 exhibits a gradual decline of about 3.6 ft, from 5923.4 ft to 5919.8 ft amsl.

3.0 Summary

Beginning in 1992, transducers were installed in the regional aquifer test wells at LANL for measuring and recording water level on a regular basis. The transducer data are not continuous and for each well the periods of transducer data are different due to transducer failures, data logger malfunction, data corruption, and personnel limitations.

3.1 Annual Water Level in Test Wells

Table 18 summarizes representative annual water level data for the test wells from 1992 to 2003. The representative annual water level was compiled from manual water level measurements and transducer water level data to provide a representative water level for each year. Appendix Table A-1 lists the annual water level data for the entire period of record for the test wells.

Table 18. Representative Annual Water Level in Test Wells, 1992 to 2003

Year	TW-1	TW-2	TW-3	TW-4	TW-8	DT-5A	DT-9	DT-10
1992	5831.8	5856.4	5819.8	6072.6	5882.1		5921.0	
1993	5824.5	5855.2	5819.1	6071.9	5880.9	5961.2	5920.9	5923.4
1994	5821.0		5817.0		5880.6	5961.1	5920.7	5923.3
1995	5818.8		5816.1		5879.7	5961.6	5920.4	5923.2
1996	5815.7		5814.7		5878.6	5961.4	5920.0	5922.7
1997	5829.0		5813.7	6072.2	5878.5		5919.5	5922.3
1998		5850.3		6072.3			5919.2	5922.1
1999			5812.5	6072.4			5918.9	5921.3
2000	5869.5	5847.7		6072.4	5875.7	5960.2	5918.3	5920.7
2001	5865.0		5812.0	6071.9	5875.6	5959.1	5918.0	5920.3
2002	5850.5			6071.7	5875.4	5959.0	5917.9	5920.0
2003	5840.2			6071.5	5875.5	5958.8		5919.8

Note: Values for 2003 are preliminary and subject to revision pending additional data.

The largest fluctuation in water level since 1992 has been in TW-1, where the water level increased about 55 ft from 1997 to 2000. In 2003, the water level declined to within 10 ft of the 1992 water level. The transducer in TW-2 experienced a failure in late 2000, thus water level data after that time are not currently available. From 1992 to 2000, the water level in TW-2 declined about 8.7 ft.

The water level data for TW-3 show a relatively systematic water level decline from 1992 to 1997. For the period 1992 to 2001, the water level in TW-3 declined about 7.7 ft. Water level data for TW-3 since 2001 indicate a recurring malfunction of the transducer equipment, thus data are not currently available. Further evaluation of the transducer data from TW-3 for years 2001 to 2003 is necessary pending additional water level measurements.

TW-4 has the highest water elevation of the test wells; from 1992 to 2003, the water level declined about 1 ft. The fluctuation in transducer water level data from 1993 to 1996 is not consistent with manual water level measurements and is considered invalid (see Section 2.4).

From 1992 to 2003, the water level in TW-8 gradually declined about 7 ft, most of which appears to have occurred before 2000. From 2000 to 2003, the water level in TW-8 did not change significantly.The DT wells at TA-49 show an average water level decline of about 3 ft for the 10 years since 1992.

Figure 12 shows the annual water level in the test wells from 1949 to 2003. Annual data prior to 1992 are from Koch and Rogers (2003) and data from 1992 to 2003 are from Table 18; all data are summarized in Appendix Table A-1. The water levels in TW-1, TW-2, TW-3, and TW-4 were relatively stable through the 1950s and 1960s; TW-1 shows a slight increase in water level beginning about 1960 whereas TW-2 and TW-3 show a slight decline in water level at that time. The water level in TW-1 in

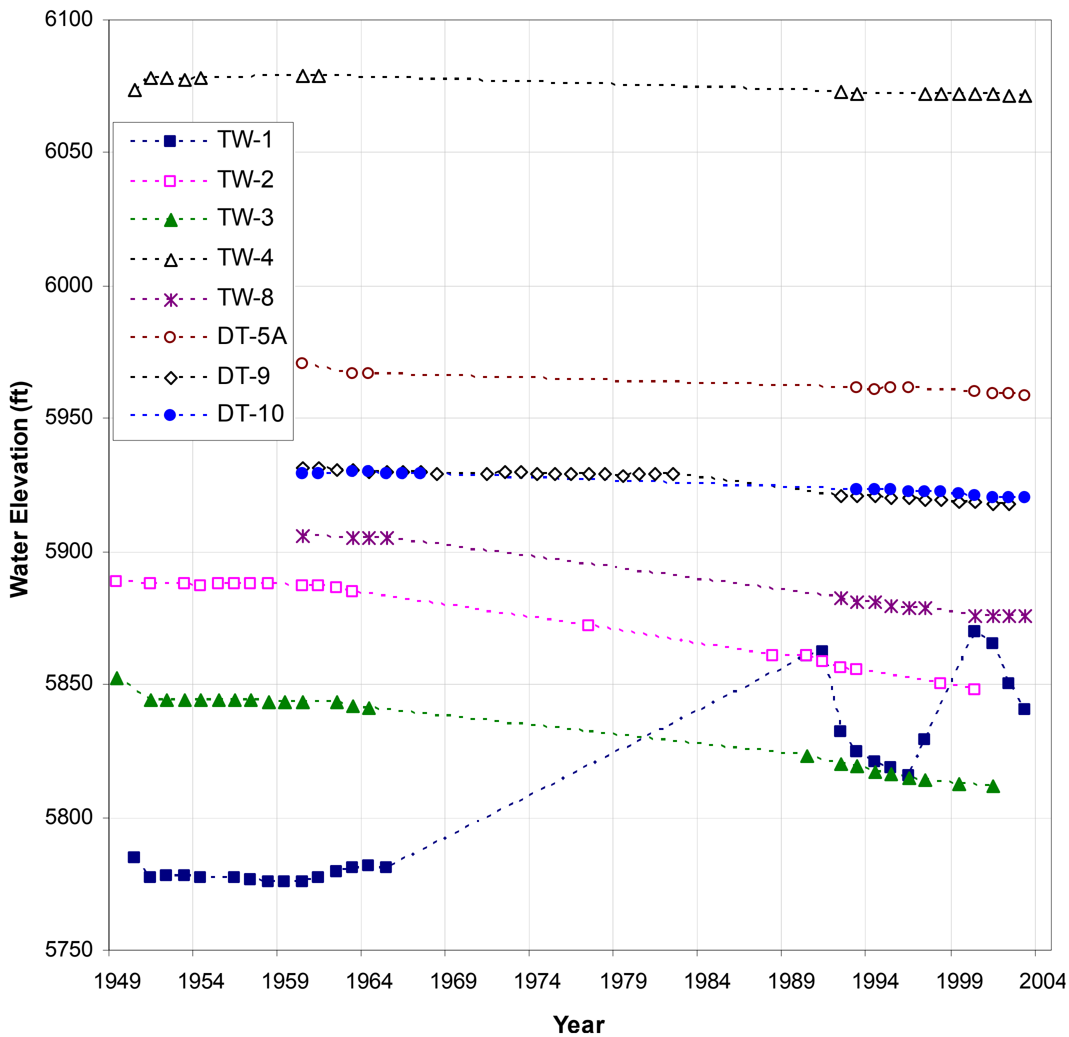

Figure 12. Annual water level in the test wells, 1949 to 2003.

1990 was 80 ft higher than in 1965, water level data during the intervening years are not available, but the probable explanation for the higher water level is increased infiltration of runoff and effluent from Pueblo Canyon (see Section 2.1).

TW-8, DT-5A, DT-9, and DT-10 were installed in 1960; the water level in these wells was relatively stable in the 1960s. In 1992, the water level in TW-8 was about 23 ft lower than in 1965 and shows a steady decline during the 1990s; however, from 2000 to 2003 the water level in TW-8 has been relatively stable. TW-3 also has a relatively steady decline from 1990 to 1999.

Figure 13 shows the yearly change from initial water level for the test wells. The water level in TW-1 began to rise about 1960 and the water level rose about 5 ft in 5 years. In 1991, the water level in TW-1

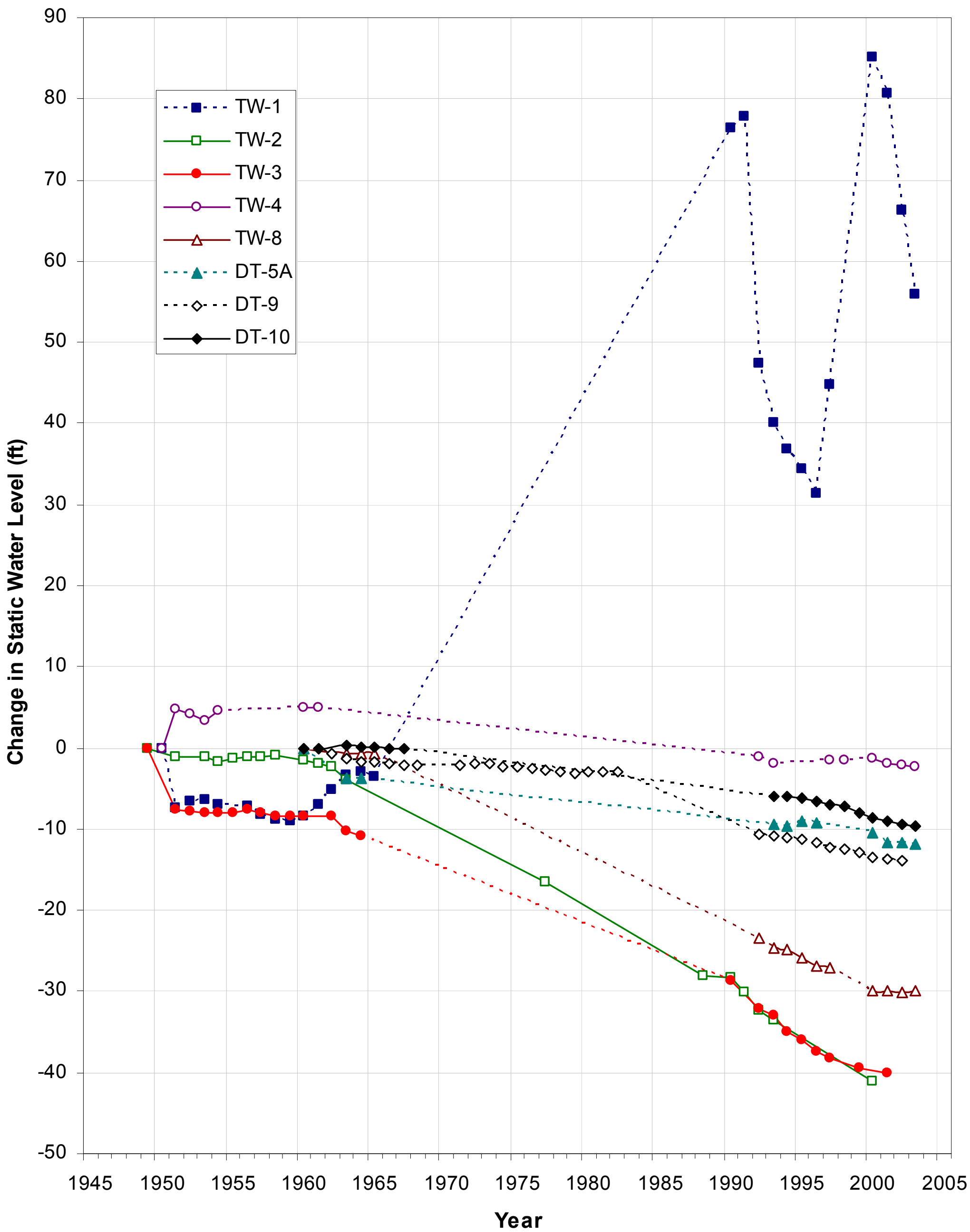

Figure 13. Annual change in water level in test wells, 1949–2003.

was about 78 ft higher than the initial water level in 1950. The water level declined about 46 ft from 1992 to 1996, but increased about 54 ft from 1996 to 2000. From 2000 to 2003, the water level in TW-1 has declined about 30 ft.

TW-2 and TW-3 have the largest overall water level declines, of about 40 ft. Both wells show an increase in the decline rate beginning about 1990, but since 2000, water levels have not declined as much as in the 1990s. TW-8 has a total water level change of about 30 ft since 1960, but no significant change since 2000.

From 1960 to 1982, DT-9 shows a water level change of about 3 ft over 22 years (Purtymun 1984). From 1992 to 2002, the water level in DT-9 changed 3 ft in 10 years, indicating a greater decline rate. DT-5A and DT-10 show similar changes in water levels from 1993 to 2003. The DT-9 water level data indicate a 7.8 ft decline between 1982 and 1992, during which no manual water level measurements were apparently obtained. Compared with the apparent steady and slower rate of decline for nearby wells DT-5A and DT-10, this decline in DT-9 suggests that different measuring point datums may have been used for the water level measurements before 1982 and after 1992. However, we were unable to find field records of water level measurements before 1992 to identify the source of this possible error. As discussed below, the overall water level decline and rate of decline since drilling for DT-9 is larger than for DT-5A and DT-10.

3.2 Water Level Rate of Change

Table 19 summarizes the average annual rate of static water level change since the test wells were initially installed, and for the period 1992 to 2003. We report both the overall rate and the rate for the last decade because the recent rate of decline in several wells has changed significantly. These values for rate of decline might be used to determine screen depths for new monitoring wells based on the desired lifetime for the well. When determining needed screen depths, the location of a new monitoring well relative to water supply pumping and to wells used to evaluate rate of decline should be considered carefully.

The overall rate of change is based on the initial water level, the most recent water level, and the number of years between the initial and recent water level data. For TW-1, TW-3, and TW-4, the initial water levels were not used for the rate of change calculations because the initial water levels obtained when the wells were drilled vary significantly from succeeding values (see Figure 13). For these wells, the water level remained stable for several years after drilling, except for the initial water level; thus, we used the 1951 water level data to calculate the annual rate of change.

In 2003, the water level in TW-1 was about 63 ft higher than in 1951 for a rate of +1.22 ft/yr. The largest overall rate of water level decline was –0.80 ft/yr at TW-2 where the water level was 41 ft lower in 2003 than in 1949. TW-3 and TW-8 have similar rates of change, and –0.64 ft/yr and –0.69 ft/yr, respectively. The DT wells at TA-49 show water level declines ranging from about 10 to 14 ft over 42 to 43 years, for an annual rate of change ranging from –0.22 to –0.33 ft/yr.

Table 19 also shows the recent rate of water level change from 1992 to 2003 using the representative annual water level data from Table 18. From 1992 to 2003, the rate of change at TW-2, TW-3, and DT-10 was higher than the overall rate of change. The highest rate of water level decline for this period was –1.09 ft/yr at TW-2. The recent rate of change for TW-4 was about 74% of the overall value; the recent rate was about the same as the overall rate for TW-8, DT-5A, and DT-9.

Figure 14 shows the annual rate of water level change in the test wells for the period 1992 to 2003. The map of groundwater level change rates is preliminary and subject to change with additional data. The contours indicate a zone of larger annual water level declines that extends from TW-2 to TW-8; here annual declines are from 0.65 to 1.09 ft/yr. A groundwater mound is shown around TW-1, where the water level has shown a recent average annual increase of 0.77 ft/yr. The extent of this groundwater mound is not known, so we show an interpretive extent of the mound in Figure 14. The groundwater mound near TW-1 is likely due to infiltration of runoff and effluent from the Los Alamos County sanitary treatment plant (see Section 2.1).

Table 19. Annual Rate of Change of Water Level in Test Wells

Well	Initial Water Elevation (ft)	Initial Elevation Year	Recent Water Elevation (ft)	Recent Elevation Year	Overall No. Years	Overall Water Level Change since Installation (ft)	Overall Rate of Change since Installation (ft/yr)	Water Elevation ca. 1992 (ft)	Year	Recent No. Years	Recent Water Level Change since ca. 1992 (ft)	Recent 1992 - 2003 Rate of change (ft/yr)	Recent Decline Rate /Overall Decline Rate Ratio
TW-1	5776.9	1951	5840.2	2003	52	63.3	1.22	5831.7	1992	11	8.5	0.77	0.63
TW-2	5888.7	1949	5847.7	2000	51	-41.0	-0.80	5856.4	1992	8	-8.7	-1.09	1.35
TW-3	5844.4	1951	5812.2	2001	50	-32.2	-0.64	5819.8	1992	9	-7.6	-0.84	1.31
TW-4	6078.5	1951	6071.5	2003	52	-7.0	-0.13	6072.6	1992	11	-1.1	-0.10	0.74
TW-8	5905.5	1960	5875.5	2003	43	-30.0	-0.70	5882.1	1992	11	-6.6	-0.65	0.93
DT-5A	5970.7	1960	5958.8	2003	43	-11.9	-0.28	5961.2	1993	10	-2.4	-0.24	0.87
DT-9	5931.7	1960	5917.9	2002	42	-13.8	-0.33	5921.0	1992	10	-3.1	-0.31	0.94
DT-10	5929.3	1960	5919.8	2003	43	-9.5	-0.22	5923.4	1993	10	-3.6	-0.36	1.63

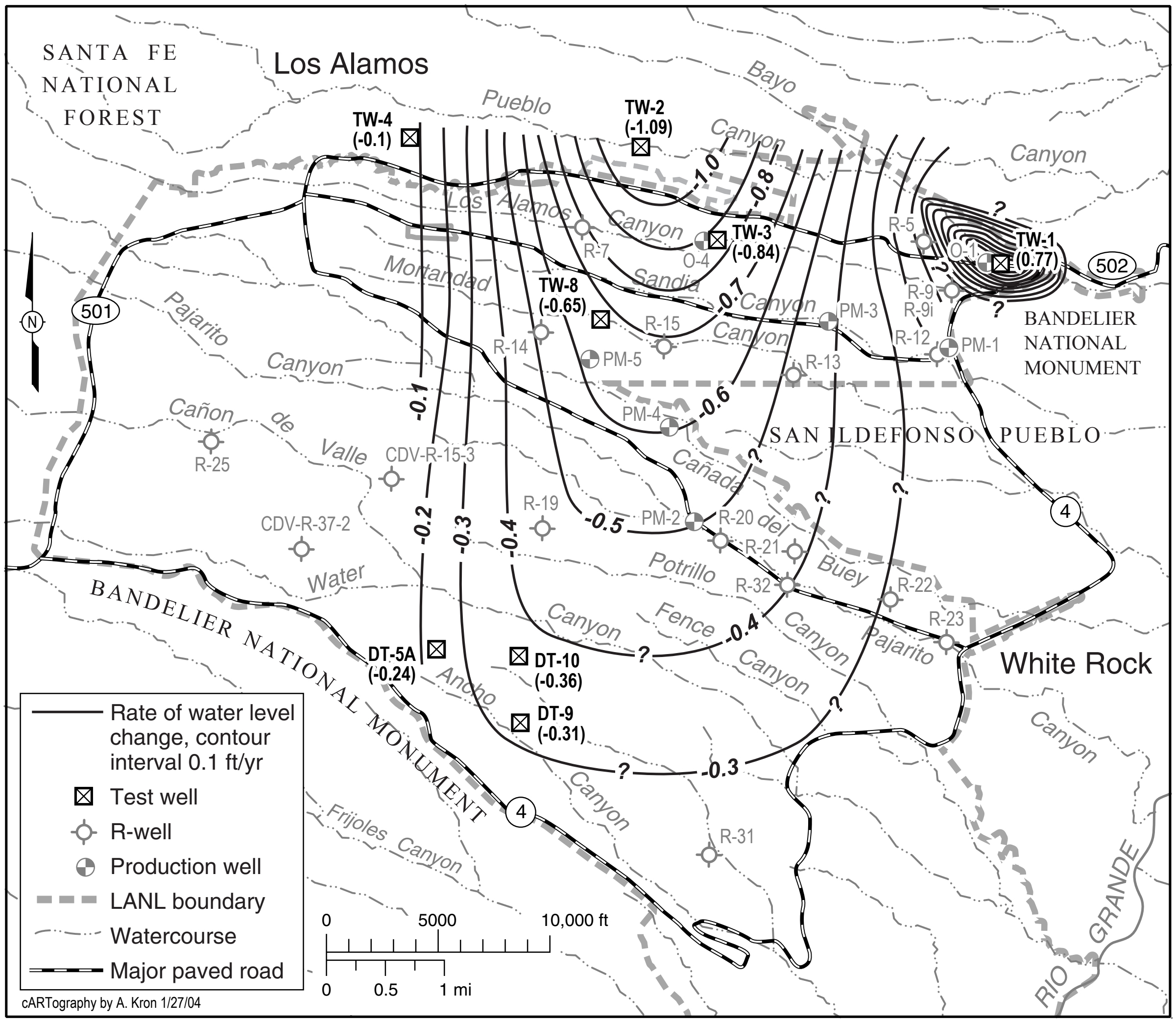

Figure 14. Map showing annual rate of change of water level in test wells, 1992–2003 (ft/yr).

The groundwater level declines are probably the result of groundwater withdrawals from the three well fields at Los Alamos, the Guaje, Otowi, and Pajarito Mesa well fields (Koch and Rogers 2003). Because the test wells are completed within the top 100 to 600 ft of the regional aquifer (and have screened lengths of 10 to 460 ft), which is relatively shallow compared with the screened depths of the water supply wells, the annual rate of water level change shown in Figure 14 applies to the upper part of the aquifer in the vicinity of the test wells only, and may not represent water level changes within the deeper portion of the aquifer affected by water supply withdrawal.

3.3 Recommendations

The data we present in this report lead to some recommendations for future transducer water level measurements:

- Standardize water level measurement procedures and transducer installation procedures.
- Transducer cables must be securely fixed to the top of the well casing to prevent slippage, and a reference marking provided at installation to detect slippage or tampering.
- New transducer cables must be deployed for some time prior to measurements to allow for cable stretch.

- For single completion wells, manual water level measurements must be obtained and properly documented when transducers are installed and removed.
- Manual water level measurements should be obtained every three to six months to verify the transducer measurements.
- Single completion wells equipped with transducers require separate accommodation for manual water level measurements. Transducers are deployed through a PVC tube extending from the wellhead to the water table to avoid tangling of the transducer cable with the pump column. Without an additional access tube to accommodate water level measurement tape, the transducer must be removed each time a manual water level measurement is obtained.
- Wells equipped with transducers must be protected from intrusion or disturbance; care must be taken during sampling or well maintenance, etc., so the transducer is not disturbed.
- Transducers must be checked within a few weeks of installation to ascertain that the equipment is functioning properly, and rechecked every few months during deployment of the transducer equipment.
- Archive original binary data files to provide a record for future evaluation of the data.

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6.0 Appendix A.

Table A-1. Annual Groundwater Elevation in Regional Aquifer Test Wells (ft amsl).

Sfc Elev (ft)	6369.2	6647.6	6595.3	7244.6	6873.5	7143.9	6935.0	7019.9
Initial Elev. (ft)	5784.3	5888.7	5852.0	6073.8	5905.5	5970.7	5931.7	5929.3
Year	**TW-1**	**TW-2**	**TW-3**	**TW-4**	**TW-8**	**DT-5A**	**DT-9**	**DT-10**
1949		5888.7	5852.0					
1950	5784.3			6073.8				
1951	5776.9	5887.5	5844.4	6078.5				
1952	5777.8		5844.3	6078.0				
1953	5778.0	5887.7	5843.9	6077.1				
1954	5777.4	5887.0	5843.9	6078.4				
1955		5887.4	5844.0					
1956	5777.2	5887.7	5844.4					
1957	5776.1	5887.7	5844.0					
1958	5775.4	5887.9	5843.6					
1959	5775.3		5843.5					
1960	5775.8	5887.1	5843.5	6078.7	5905.5	5970.7	5931.7	5929.3
1961	5777.4	5886.8		6078.7			5931.6	5929.3
1962	5779.2	5886.4	5843.5				5931.0	
1963	5780.9	5884.8	5841.7		5904.8	5967.0	5930.4	5929.6
1964	5781.4		5841.1		5904.8	5966.9	5930.0	5929.5
1965	5780.8				5904.8		5929.9	5929.4
1966							5929.8	5929.3
1967							5929.6	5929.3
1968							5929.5	
1969								
1970								
1971							5929.5	
1972							5929.8	
1973							5929.7	
1974							5929.4	
1975							5929.4	
1976							5929.2	
1977		5872.1					5928.9	
1978							5928.8	
1979							5928.6	
1980							5928.8	
1981							5928.8	
1982							5928.8	
1983								
1984								
1985								
1986								
1987								
1988		5860.6						
1989								
1990	5860.8	5860.4	5823.3					
1991	5862.2	5858.6						
1992	5831.8	5856.4	5819.8	6072.6	5882.1		5921.0	
1993	5824.5	5855.1	5819.1	6071.9	5880.9	5961.2	5920.9	5923.4
1994	5821.0		5817.0		5880.6	5961.1	5920.7	5923.3
1995	5818.8		5816.1		5879.7	5961.6	5920.4	5923.2
1996	5815.7		5814.7		5878.6	5961.4	5920.0	5922.7
1997	5829.0		5813.7	6072.2	5878.5		5919.5	5922.3
1998		5850.3		6072.3			5919.2	5922.1
1999			5812.5	6072.4			5918.9	5921.3
2000	5869.5	5847.7		6072.4	5875.7	5960.2	5918.3	5920.7
2001	5865.0		5812.0	6071.9	5875.6	5959.1	5918.0	5920.3
2002	5850.5			6071.7	5875.4	5959.0	5917.9	5920.0
2003	5840.2			6071.5	5875.5	5958.8		5919.8

Note: Pre-1992 data from Koch and Rogers (2003), Post 1992 data from this report

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